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ABSTRACT

Many information systems have failed to achieve their promised potential because of the inability of the analyst to design a system that was attuned to the needs of the decison maker. To remedy this situation, it is essential to develop tools that facilitate the process of defining distinct decision parameters, understandable by the decision maker, the analyst, and others in the organization.

The primary purpose of this paper is to present, develop, and test a methodology for eliciting the information used, or desired to be used, by decision makers in choice-set environments. Additionally, guidelines are suggested for incorporating the methodology into the design of an information system

In recent years, there has been a growing concern over the inability of information systems to fulfill their promised potential. Although many reasons have been advanced as to why information systems are often profit absorbers rather than profit producers, none appears more cogent than that offered by the American Accounting Associatoin Committee on Management Information Systems (1974)

> ...decision-makers are often poor judges as to the information they really need. On the one hand, they quite often overlook information that would be very valuable to them; on the other hand, they often call for more data than they can realistically use.

To ameliorate situations of the type described by the Committee, Mason and Mitroff (1973) call for the application of methodologies which generate information geared to the psychology and attuned to the problems of the decision maker.

The purpose of this study is to present, develop, and offer evidence in support of a methodology for eliciting information relevant to decison making processes. The focus of the methodology is on making explicit, through measurement, the decision maker's cognitive structure[1] of information sources.[2] In a general sense, the methodology is intended to provide a framework for discerning (1) the identifiable information sources within the cognitive realm of a decision maker, and (2) the salient characteristics, (e.g., degree of objectivity, understandability) decision makers attach to these information sources.

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[1] The cognitive structure is that which allows an individual to process, in an active manner, environmental stimuli. Processing may take the form of responding, naming, discriminating, and analyzing information (Garner, 1966).

In the first section of the paper, a brief outline is given concerning the nature of the measurement problem and the origins of the proposed methodology. The research methodology is developed in the second section of the paper. In this section, the experimental setting is identified, the experimental sample is defined, the data collection procedure is given, and the hypothesis and validation framework are specified. In the third section of the paper, validation results are presented and a sample of a derived map of information sources is given. In the last section of the paper, an outline is offered of stages in the design cycle of an information system where the methodology appears applicable.

BACKGROUND OF THE MEASUREMENT PROBLEM AND PROPOSED METHODOLOGY

In situations where choices must be made, an individual decision maker relies on information to describe the parameters of the choice environment. In the case of an uncertain choice environment, information refers to data which changes the decison maker's prior probability distribution of outcome states. If the intent of our investigation is to describe, versus prescribe, the information used by individuals within a choice environment, we may either directly study the decision maker making decisions, or indirectly formulate, through measurement, the dimensions of a decision maker's information model. While the former approach, often referred to as direct modeling of the decision network, has provided an array of conceptual tools for analyzing the decision process, the latter approach will be followed in this paper because of its feasibility. That is, given the demands placed upon the analyst and the individual under study in terms of time and effort, the ability of an indirect measurement procedure to formulate a structure of information needs is felt to be sufficiently favorable to warrant its adoption.

Indirect formulation of an information structure addresses three key issues: (1) of the universe of information sources, what are the identifiable information sources which pertain to a particular decision environment, (2) what are the important attributes[3] which characterize the identifiable information sources, and (3) how is each identifiable information source rated on each important attribute.

In the past, researchers have utilized some form of scaling method (e.g., the semantic differnetial) coupled with a data reduction technique. For example, individuals may be requested to rate a prespecified list of information sources on a set of prespecified adjective scales. The analysis that follows (e.g., factor analysis) attempts to remove redundant adjective scales, thereby simplifying the attribute structure.

There are two inherent limitations to the above procedure. First, it may be difficult to devise a set of information sources and adjective scales which are relevant to the problem at hand for all respondents. The sources and scales may not be understood, or worse yet, misunderstood if they are not in the respondent's own vocabulary. Further, the fineness of scale (number of categories) is designer rather than respondent based. As such, the respondent may

[2] An information source is defined as the specific kind, class, origin, or order of information. Examples of information within this rather broad definition might be: other people, past experiences, resource documents, statistically summarized data, and financial statements.

[3] An attribute may be defined as the inherent quality, interpretation, or classification of an information source.

be forced to discriminate among shades of grey where only black and white exists. Second, while such traditional techniques as factor analysis are excellent at removing redundancy, their facility in generating a joint space (map) of information sources and attribute dimensions is questionable.

The Rep Test

One methodology which overcomes the limitation of information source and attribute scale relevancy is Kelly's (1955) Role Construct Repertory Test (Rep Test). Methodologically, the Rep Test is an application of the concept-formation test. Unlike traditional concept-formation tests, however, the Rep Test deals with particular items (people), rather than levels of abstraction. The aim of the Rep Test is to develop role constructs or concepts played out in the light of a subject's understanding of a familiar person (Mansuso, 1970).

The Rep Test methodology would appear to be particularly applicable to the definition of environments which embody the following characteristics:

1. A large number of possible objects on which judgments must be rendered.
2. A large number of possible attributes which could be used as a basis for judgment formulation.
3. An absence of, or diversity among, measurement analogues for the possible attributes.

Here, definition is meant to encompass only the initial unraveling of an intertwined, nebulous environment. To go beyond the stage of identification of general functional relationships beteen the objects and the attributes, requires the application of additional techniques (e.g., the techniques associated with the Brunswick "lens" model (Ashton, 1974; 1975)).

To reinforce the above point, consider the extensive experimentation into the applicability of the Rep Test methodology that has been carried out by Jarrod Wilcox (1970; 1972). Specifically, Wilcox investigated the feasibility of an adapted version of Kelly's methodology with respect to measuring decision assumptions held by market participants (professional investors) concerning common stocks. On a qualitative basis, Wilcox states that:

> Straightforward questioning of decision-makers as to what attributes they use in coming to a decision is often unworkable because they don't know. However, by getting the decision-maker to compare the intersimilarities of familiar alternatives a few at a time, specific pertinent semantic strucutres are exercised and can be identified and labeled. This is done through the role repertory test (Wilcox, 1972).

However, on a quantitative basis, judging the success of the methodology as a vehicle for measuring decision assumptions on correlations between actual respondent preferences of new data and predicted respondent preferences from derived models, Wilcox found that:

> In the stock market participant study, the previously estimated models of decision assumptions accounted, on average, for only about a third of the individual's variance in preference ratings. This average explanatory power is quite modest, but includes some cases of outright failure and some of great success (Wilcox, 1972).

RESEARCH METHODOLOGY

The setting chosen for the experiment was a laboratory. The specific form of laboratory experimentation selected was experimental gaming, involving what is more commonly known as a management game.[4] The game selected for the experiment attempted to match, from the standpoint of complexity of decision environment, the backgrounds of the participants.

Participants for the experiment were drawn from three sections of an undergraduate managerial accounting course offered at the University of Massachusetts. Nineteen teams were formed from sixty-five participants. The actual makeup of each team was done through random assignment by the investigator.

The data collection design consisted of the following five steps: 1. Following the third decision period, a questionnaire was distributed to all participants. The intent of the questionnaire was to elicit the role played by various sources of information in the decision maker's conceptual structure of the simulation environment. For example, whereas Kelly asked individuals under study to identify a familiar person who they thought best fits the role of the most interesting person they knew, and Wilcox asked investors to identify the common stock which best fits the role of their present favorite stock, this questionnaire asked game participants to identify that source of information which best fits the role of being difficult to understand. Of the sixteen questions asked (see Table 1), six of the questions related to planning decision roles, two to control decision roles, and the remaining eight, to more general roles. It should be mentioned that there is no implication here concerning either an optimal number of total questions or an optimal number of questions within a category. The original list of questions numbered well over twenty-five; pruning of the original list was based on pretest understandability of each of the questions. In fact, it is my opinion that an exhaustive list of questions be presented to the respondents, subject to the constraint that a large number of the respondents completely refuse to complete the questionnaire. By making the list of questions as exhaustive as possible, at worst, responses for the sake of responding ("throw away" information sources) will be elicited. These "throw away" information sources can be identified and a method for doing so is discussed in the Experimental Results section of the paper.

On the reverse side of the questionnaire, each participant was asked to identify the team member most responsible for planning decisions. If there was a consensus in response to this question, the individual identified became the sole subject of further investigation. For those cases where a consensus did not exist, further investigation proceeded with all identified members of that team.[5]

2. From the questionnaire of the identified individual or questionnaires of the identified group, a limited number of triads of information sources was formed. The intent of triad formation was to elicit, for differing combinations of information

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[4]The particular game chosen was AGELCLAP, a multiperiod, interactive managerial accounting game that emphasized planning and control decisions. In each period, players were faced with decisions concerning product price, promotion, R&D, volume of production and purchases, hiring and firing of production employees, and financing (borrowing and investing).

[5]A consensus did not exist for five of the nineteen teams.

Table 1. Information Source Role List

1. The source of information your used to make a decision that resulted in a substantial profit.
2. The source of information you used to make a decision that resulted in a substantial loss.
3. The source of information which, at first, was not crucial to your control decisions, but not is.
4. The source of information most stronly debated by your team.
5. The source of information you consider crucial to the planning process.
6. A source of information you favor but your team does not.
7. A source of information you consider important to the control process.
8. The source of information which, at first, was not important to your planning decisions, but now is.
9. A source of information you feel you understand well.
10. A source of information recommended by the instructor for planning decisions you should have used but did not.
11. A source of information provided in the game instructions which proved valuable to planning decisions.
12. A source of information you feel is difficult to understand.
13. A source of information recommended by your instructor you found wasn't important.
14. A source of information you feel would be of value to the value to the planning process, but could not obtain.
15. A source of information which, if changed from its present form, would contribute materially to your planning decisions.
16. A source of information you consider misleading.

sources, attributes which described the information sources in the respondent's own terms.

The number of triads formed was equal to the number of information sources elicited from the questionnaire. As such, each information source appeared in exactly three triads. Although the choice of three was somewhat arbitrary, the choice was influenced by the tradeoff between participant fatigue and adequate comparison exposure of each of the information sources. Triad order of presentation was done on a random basis. Similarly, both the ordering of information sources within each triad, and triad formation itself was randomized, with the sole consideration that no two information sources appear together in more than one triad.

3. Each individual or group was then interviewed.[6] In the interview, the examiner attempted to elicit similarities (constructs) and differences (contrasts) for each of the formed triads of information sources. He asked, "I would like you to tell me something about these information sources. Which two are most alike, and in what important way are they alike?" For the third information source in the triad, he asked, "How is this information source different?" He then repeated this process for each of the remaining triads.

The dialogue of each interview was tape recorded. In most instances the interviews lasted from 25-40 minutes. The length of these interviews was largely a function of the degree of response specificity which could be obtained. For example, if a response was given "Both are unreliable," when identifying a construct for a pair of information sources, the interviewer would be required to engage in a series of probing questions. He might ask, "Is there something about their being unreliable which seems to make them alike?"

4. Upon completion of all interviews, the tapes were reviewed and adjective scales formed for each construct. It should be noted that constructs concerning multiple triads were often repeated; likewise, but on a less frequent basis, more than one construct was generated for a single triad. For this reason, a yield ratio of adjective scales to triads of less than one was achieved.

5. The initial questionnaire and sets of adjective scales were returned to the individuals with the request that each information source be ranked[7] on each adjective scale. For those information sources inappropriate to a specific adjective scale, a category labeled "Scale does not apply," was provided.

Experimental Hypothesis

The hypothesis to be tested in this study is as follows:

> Those decision makers having more complex cognitive maps, and relying more heavily on externally generated data or internally transformed data will outperform, in a planning sense, those decision makers having less complex cognitive maps, and relying less on externally generated data or internally transformed data.

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[6]The examiner was a graduate student experienced in conducting interviews of this type and familiar with the interview procedure used by Kelly.

[7]By ranking information sources on adjective scales, an attempt was made to overcome the previously mentioned fineness of scale problem.

This hypothesis relates to the scenario proposed by Robert Anthony (1965). In the area of planning and control systems, Anthony has proposed a framework which consists of three elements: strategic planning, management control, and operational control.

> Strategic planning is the process of deciding on the objectives of the organization, on changes in these objectives, on the resources used to attain these objectives, and on policies that are to govern the acquisition, use, and disposition of these strategies (Anthony, 1965).

On the other hand, the purpose of management and operational control is the effective and efficient application of resources to achieve the organization's objectives.

Although these elements or subsystems are clearly related, because each has a different purpose and set of characteristics, a distinctive way of thinking about each is required. Specifically, Anthony suggests distinguishing the two elements on the characteristics[8] of complexity and nature of information relied on. He feels that strategic planning involves the consideration of many variables. This can be contrasted to management and operational activities which entail far fewer variables, and hence, can be considered a less complex process. Likewise, Anthony suggests that strategic planning relies heavily on external information collected from outside the operating entity, or internally generated information that has been recast to fit the needs of the problem being analyzed (Anthony, 1965).

Validation Framework

To make the testing of the hypothesis operative, it was first necessary to specify how each variable (information source reliance, complexity of cognitive structure, and planning performance) was quantified, and outline how these quantified variables were incorporated into a statistical model.

Information Source Reliance. A source of externally generated information is defined as one which does not emanate from the game explanation, game printout of financial statement data, and competitors' selling price and sales volume, or another member of the decison maker's team. Data that had its origins in the game explanation or printout, but had been transformed by some means (e.g., regression analysis), were defined as internally transformed data. From the subjective evaluation of information sources elicited from the information source role questionnaire, a proportion measure of external-internal information source reliance was computed for each team. The form of the measure was as follows:

$$\text{Proportion of external sources} = \frac{\text{Number of External Sources}}{\text{Total Number of Sources}}$$

The inference made was that the larger the proportion, the greater was the reliance by a team on external information sources.

Complexity of Cognitive Structure. Complexity of cognitive structure was defined as the number of nonredundant (orthogonal) attributes or dimensions related to a set of

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[8]Other characteristics include focus of pans, degree of structure, communication of information, purpose of estimates, persons primarily involved, number of persons involved, mental activity, source discipline, planning and control, time horizon, and appraisal of the job done (Anthony, Dearden, and Vancil, 1972).

information sources. It should be noted that this definition of cognitive complexity is consistent with Bieri's (1955) definition.

A measure of complexity of cognitive structure[9] was obtained by factor analyzing each set of adjective scales, and proceeding in the following way:

1. Selected from the initial factoring process, were those factors with eigenvalues larger than one.

2. A ratio was formed that consisted of the number of selected factors divided by the number of input adjective scales. A ration of one meant that a decision maker perceived each adjective scale to be unique; a ratio near zero meant that a decison maker perceived the set of adjective scales as entirely redundant. Thus, the inference was made that the higher the ratio, the higher the cognitive complexity of the decision maker.

3. This ratio was then multiplied by the inverse of the percentage of variance attributable to the selected factors. The rationale for this step can be explained by the following example. Assume that two decision makers (A and B), each rate an equal number of adjective scales. Suppose that only a single factor is derived, in both cases, by our factor analytic solution. From step 2, an identical ratio would be computed for both decision makers. Now suppose that the eigenvalue for the derived factor of decision maker A was twice that of the eigenvalue for the derived factor of decision maker B. While an equivalent redundancy could be inferred for both decision makers' derived cognitive maps, the <u>strength</u> of the redundancy surely lacks inferential equivalency. Thus, redundancy (the ratio compiled in step 2) was weighted by the strength of the redundancy (the inverse of the variance attributable to the selected factors).

4. Finally, the resultant measures were rank ordered.

This rather involved procedure was necessary because of the varying number, among teams, of information sources and adjective scales.

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[9] Because the data resulting from the second questinnaire were less than intervally scaled, an algorithm capable of reducing an arbitrary matrix to Gramain form of equal rank is called for. Such an alogrithm and accompanying program (SSA-III), has been proposed by Lingoes and Guttman (1967).

The SSA-III procedure addresses itself to representing the ordering of derived measures (in this case a correlation matrix), with a minimum number of parameters, (in this case dimensions). Three principles are involved in obtaining a solution: a) the interactive method of refactoring for a fixed number of dimensions using orthogonal transformations to improve communality estimates; b) linear transformations on an Euclidean coordinate system, $(XX'=\Theta)$ to maximize the predictability of the correlation matrix R; and c) rank-image cell-wise permutations of the Θ matrix (Lingoes and Guttman, 1967, pp. 488-9). Rank-image means a matrix Θ whose rank order is identical to the correlation matrix R. When a perfect nonmetric fit is obtained, each pair of coefficients $(r(ij) \geq r(kl)$ from R, monotonically corresponds to a pair of coefficients $(\Theta ij \trianglerighteq \Theta kl)$ from Θ.

Two things need be mentioned at this point. First, the following descriptive statistic was applied as a criterion for determining minimum dimensionality:

$$K = 1 - (r_{r\theta}^2 / r_{\theta\theta}^2)$$

The value K, permitted an evaluation of the lack of monotonicity (bending) of the Shepard diagram. In this instance, the Shepard diagram related R to θ for $i \neq j$. Drawing on the experience of Lingoes and Guttman (1967, p. 493), dimension reduction terminated when K was greater than 0.05.

Second, in a number of instances, information sources were placed in the category, "Scale does not apply." The net effect of placing information sources in this category was to create missing data. To handle data of this type, the following procedure was adopted:

1. If more than 40% of the information sources were placed in the cateogry "Scale does not apply," the adjective scale was considered irrelevant (a "throw away"), and deleted from the input adjective set. In total, 22 out of 191 (11.5%) adjective scales were removed from further consideration for this reason.

2. For those adjective scales having less than 40% of the information sources designated as "Scale does not apply," the midrank of the ordered information sources was computed. The information sources placed in the category "Scale does not apply," were then assigned the midrank value. For example, if twelve information sources were ordered on an adjective scale and two information sources were placed in the category "Scale does not apply," these two "missing" information sources were each assigned the midrank value of 6.5, thereby effectively neutralizing both information sources.

Planning Performance. Planning performance was quantified by adopting a measure proposed by Daily (1971). Daily, in essence, casts planning performance in standard deviation terms. He first defines accuracy as:

$$\text{Accuracy} = \frac{\text{Forecasted Results}}{\text{Actual Results}} \times 100$$

and then, measures precision as:

$$\text{Precision} = \sqrt{\frac{\sum_{i=1}^{N} \left(\text{Accuracy}_i - \frac{\Sigma \text{Accuracy}}{N} \right)^2}{N}}$$

where N is the number of observations (Daily, 1971). A value of zero represents perfect precision; a value greater than zero, represents the degree of imprecision.

It should be noted that here, precision more appropriately means consistency of forecast accuracy. That is, a precision value of zero represents complete or perfect consistency of forecast error; a value greater than zero represents the degree of inconsistency of forecast error.

While we no doubt are interested in quantifying planning performance in terms of the consistency of forecast error, of equal concern is the exactness (accuracy) attained in planning performance. To measure exactness of planning performance, a second quantifier was used. This second quantifier considered average absolute forecast accuracy.

Mean absolute accuracy

$$= \frac{\sum_{i=1}^{N} \left(\left| \frac{\text{Forecasted result}}{\text{Actual result}} - 1 \right| \times 100 \right)}{N}$$

Here, a value of zero represents perfect exactness.

As an integral part of each decision, estimates of net income and sales volume were required to be supplied by all teams. A trial run on the data, using the values of forecasted to actual net income as components of the accuracy measure, produced average accuracy extremes of -1,588 to 622. Upon detailed inspection of this data, it was found that many of the teams, in a number of periods, operated at, or very close to, the breakeven point. Thus, a very small forecasted net income deviation (in actual dollar terms), produced a disproportionately high inexactness value. As a result, another trial run was performed, this time, substituting forecasted and actual sales volume in units for forecasted and actual net income in the accuracy formula. For this trial run, accuracy extremes of 93 to 126 were found. Since these extremes were far more reasonable than those previously obtained using net income, the variable of forecasted to actual sales volume in units became the surrogate measure for planning performance.

The Statistical Model. Using a mean split on the explanatory variable of external-internal information source reliance, and a mid-rank split on the explanatory variable of cognitive complexity, the formal model to statistically test conceptual structure was formulated as a two-way analysis of variance with interaction. Since estimating the parameters of the relationship between the explanatory variables and the planning performance measure was of interest, a dummy variable, regression model (Goldberger, 1964) of the following form was used:

$$Y = B_0X_0 + B_1X_1 + B_2X_2 + B_3X_3 + e$$

Where y = the measure of planning precision for each team.

X_0 = 1 for all observations

$$X_1 = \begin{cases} 1 \text{ for those teams with high complexity of cognitive structure} \\ 0 \text{ otherwise} \end{cases}$$

$$X_2 = \begin{cases} 1 \text{ for those teams with high external information source reliance} \\ 0 \text{ otherwise} \end{cases}$$

$$X_3 = \begin{cases} 1 \text{ for those teams with high complexity of cognitive structure and high external information source reliance} \\ 0 \text{ otherwise} \end{cases}$$

e = the disturbance, which is spherical normal.

EXPERIMENTAL RESULTS

Using average absolute accuracy as a measure of planning performance,[10] the

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[10]To test for stability in planning performance, as measured by absolute accuracy, a one-way analysis of variance was performed, using all nineteen teams, for the

overall classification structure was statistically significant at the 0.028 level.[11] What is far more illuminating, however, were the cofficients of the regression equation (see Table 2). The interaction term had, as expected, a negative coefficient. That is, for those decision makers designated as having complex cognitive structures, and using aproportionally greater amount of external information sources, average inaccuracy was reduced. Unexpected, on the other hand, were the positive coefficients for the main effects of cognitive complexity and external information source usage. Positive coefficients have meant that decision makers designated as having a complex cognitive structure and using internal information sources, or having a simple cognitive structure and using external information sources, were more inaccurate than those decision makers designated as having simple cognitive structures and using internal information sources.

Two plausible explanations can be advanced to explain this rather counterintuitive result. First, the coefficients of complexity and external-internal source usage did not display a high degree of statistical significance. This may mean the magnitude and, perhaps, the signs of these coefficients are, in fact, spurious. Second, the analogy of a "fish out of water," may be drawn. Given either a complex or simple structure, a decision maker using a noncompatible type of information may become ineffective, and as such, make relatively poorer decisions.

But why, for example, would a decision maker with a simple cognitive structure use external information sources, if he feels uncomfortable in doing so? One explanation for this behavior lies in the research area of small group dynamics. For instance, it has been shown that group problem solving is influenced by group leadership (Shaw, 1954; 1964), hetero-

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four periods under inspection. The resulting F statistic ($F(3,72) = 1.282$) was not significant at the 0.25 level.

To determine if the teams responding to the information source questionnaire was sensitized to the issues of information source usage, a paradigm of the following form (Kerlinger, 1964) was employed:

Before and After Control-Group Design

Y_b	X	Y_a	(Experimental)
Y_b	$(\sim X)$	Y_a	(Control)

The experimental group was made up of the nineteen teams previously defined: the control group consisted of seven temas drawn from another section of the same Managerial Accounting course. The notation Y_b, X, and Y_a refer, respectively, to the average absolute accuracy for the decision period prior to the completion of the questionnaire, the questionnaire treatment $\sim X$ means the null treatment), and the average absolute accuracy for the decision period immediately following the completion of the questionnaire.

The significance of the difference between scores ($Y_b - Y_a$) of the experimental and control groups was analyzed by means of a one-way analysis of variance. The results of the analysis, ($F1,23 = 1.385$) indicate no marked sensitization of the individuals responding to the questionnaire.

[11] One team was not included in the validation structure because of the midrank split on the variable of cognitive complexity.

geneity of group membership (Hoffman, 1959; Hoffman and Maier, 1961), relative status of the group members (Raven and Rietsma, 1957), and dependence of an individual on the majority (Cohen, 1963).

Although decisions were made by individuals, often, the pooling of group resources and knowledge (team decision making) may have substantially altered the decision alternative selected. This would be especially the case if a decision maker were prone to group pressure or committed to the achievement of a harmonious group relationship (Kessel, 1973). Thus, on one hand, we might be measuring by this methodology the cognitive structure of the individual, while, on the other hand, observing the planning performance of other members within the group.

A second two-way analysis of variance with interaction was performed. The same classification structure was used, except that this time precision of sales volume forecasts was the surrogate measure of planning performance. The overall classification structure was statistically significant at the 0.025 level; the regression results conformed to those results obtained using absolute accuracy as the dependent variable.

Portraying Decision Maker Maps

As previously mentioned in the first section of this paper, the technique of factor analysis, while facilitating the derivation of a parsimonious attribute structure, does not provide us with a particularly good joint space representation (map) of attributes and information sources. Toward the aim of deriving a map characterizing a decision maker's cognitive information structure, multidimensional scaling (MDS) appears to be a more appropriate analytical technique.[12]

The basic purpose of MDS is to locate objects in geometric space based on attribute ratings of these objects. Given the metric of the data (less than interval scale), a nonmetric approach is necessary. Specifically, the TORSCA 9 (Young and Torgerson, 1967) scaling algorithm was applied. An example of one team's map is shown in Figure 1. Dimension reduction terminated when stress (goodness of fit) exceeded 5% (Kruskal, 1964). Dimensions were labeled by following the procedure of first, computing a Kendall rank correlation coefficient, tau (τ) (Siegel, 1956), between the derived ordering of information sources on each MDS dimension and the respondent supplied ordering of information sources of all attribute scales, and then, naming the derived dimension based on the closest corresponding attribute scale (the attribute scale with the highest tau).[13]

Two aspects concerning the scaling solution are worth noting. First, this sample map provides us with a good starting point for the application of educational treatments. For example, it appears that members of this team found it difficult to understand such information sources as line of credit (L), calculation of inventory (K), and variance analysis (H). By reviewing what input components impact on each information source, how each input component is functionally combined to form

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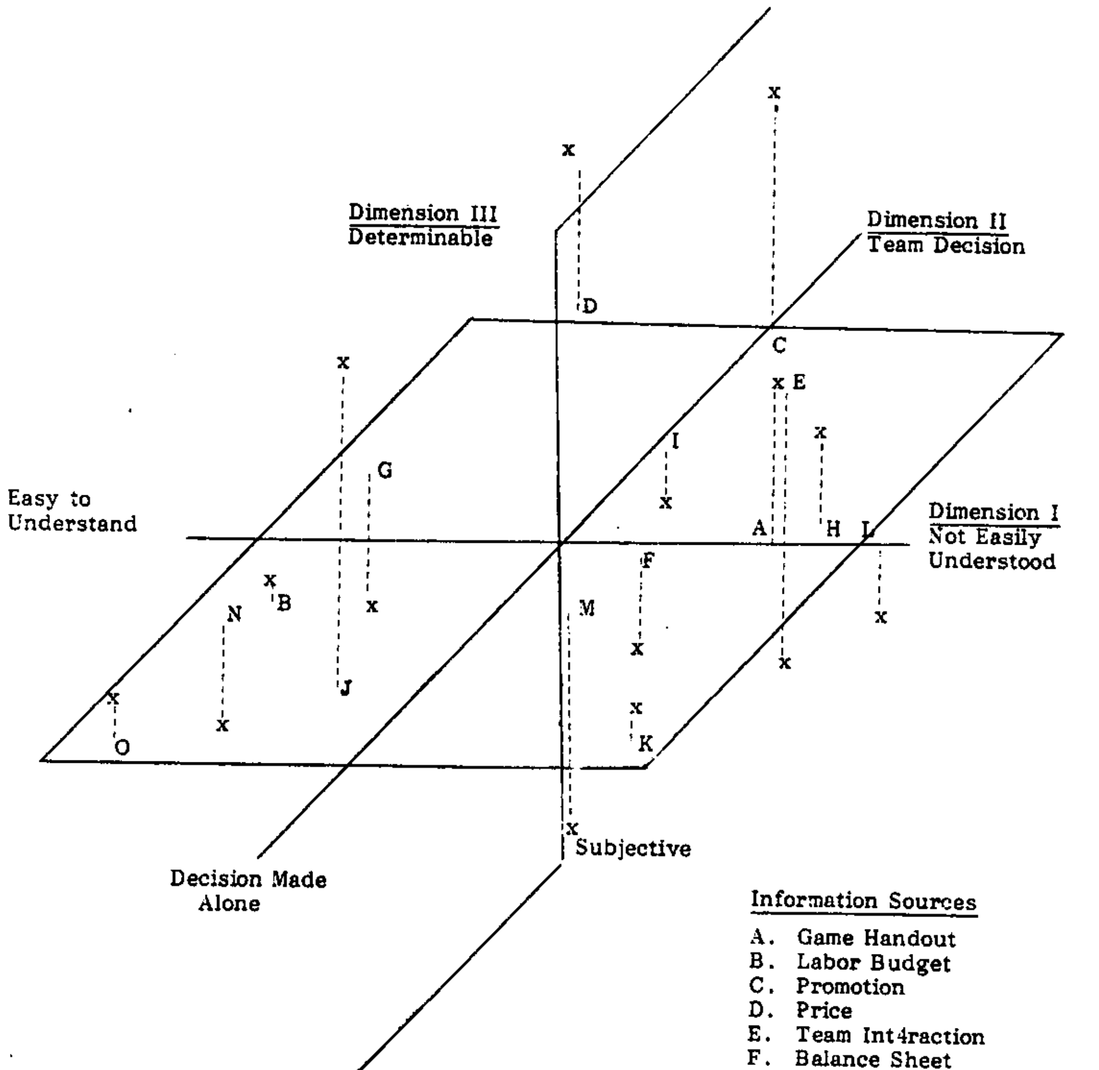
[12]For a general overview of MDS, see Krampf and Williams (1974), and Green and Carmone (1970). For a more detailed discussion of many of the theoretical issues concerning MDS, see Shepard, Romney, and Nerlove, eds., (1972).

[13]Attribute scale correspondence and level of significance were respectively $\tau = .64$, $\alpha = .0005$ for dimension I, $\tau = .75$, $\alpha = .00005$ for dimension II, and $\tau = .67$, $\alpha = .0003$ for dimension III.



Information Sources

A. Game Handout
B. Labor Budget
C. Promotion
D. Price
E. Team Int4raction
F. Balance Sheet
G. Cash
H. Variance Analysis
I. Loans and Payments
J. Miscellaneous Matters
K. Calculation of Inventory
L. Line of Credit
M. Information on Other Teams
N. Printout
O. Holding Costs

*The stress for this three dimension solution was 0.04.

Figure 1. MDS of Information Sources for One Team*

each information source, and what each information source ought to convey in a decision making sense, we would expect that these information sources would shift toward the "easy to understand" end of dimension I.

A second noteworthy aspect of the scaling solution is that not all original information sources, as elicited by the initial questionnaire, appear on the final map. In this instance, the original information sourcce designated as budget explanation was deleted from the final map, and thus classified as a "throw away" information source. Even in high dimensionality, this particular information source was located squarely on the origin. Indeed, when reference was made back to the questionnaire in which information sources were ordered on adjective scales, the budget explanation information source was either given a mid-rank order or placed in the category, "Scale does not apply."

APPLICATION OF THE METHODOLOGY TO THE DESIGN OF INFORMATION SYSTEMS

The following paragraphs outline the steps in the design of an information system where the application of the proposed methodology could prove rewarding:

1. Since many real-world decision makers cannot articulate what should be the objective or objectives of the information system, the methodology could be applied here as a valuable analytical tool. By eliciting a preliminary list of sources of information, deemed by the decision maker to be essential products of the information system, benchmarks for evaluating the performance of the information system are revealed. From the examination of the evaluative criteria, insight is provided into the nature of the objectives of the information system.

2. Given that a consensus can be reached on what are the objectives of the information system, the degree to which the present information system meets these objectives can be determined. By this assessment process, the strengths and weaknesses of the present information system should be delineated, thereby providing guidelines for either the enhancement of the present system, or evolution of a dramatically different information system.

3. Drawing on the preliminary list of sources of information, as well as the reasons a decision maker considers this information to be of importance, an in-depth investigation of the attributes of the information sources should be carried out. This indepth investigation should focus on such salient information attributes as: timeliness, level of detail, degree of summarization, accuracy, certainty, degree of quantification, and accessibility. Each source of information from the preliminary list, together with other information sources that the decision maker at first, may have overlooked, should be scaled on the attributes elicited by means of the triad comparison exercise, as well as the additional information attributes identified above.

4. A joint space, consisting of information sources and attributes, should then be constructed using the technique of MDS.

5. Following the completion of the systems design and implementation phases, and after some specified period of hands-on experience with the operational information system, the decision maker should be revisited by the analyst. The decision maker should be requested to rescale the information sources on each of the attributes. The resulting data should be resubmitted to the MDS program.

6. The output from the initial and follow-up analysis can now be compared. This

comparison should reveal differences in the spatial location of the information sources. The direction and amount of change in the location of the information sources, represent (estimate) the degree of perceptual change experienced by the decision maker over the period of time from systems analysis to the present.

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